HEAT AS A TOPIC FOR THE EXPERIMENTAL SCIENCE WORK OF THE EIGHTH GRADE[1]

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The purpose of the present paper[2] is not to give the outlines for the full year's work in the elementary science of the eighth grade, but to present one series of lessons in sufficient detail to show exactly what was done by the pupils, and the conclusions that they made from their experiments. Therefore, but a brief statement is made of the work that has preceded the topic here outlined, and another of the work that follows. Essentially the same method of work was used with the other topics as with that here given.

The topics of the seventh grade which were related to physical phenomena dealt chiefly with electricity and magnetism, the pupils constructing most of the apparatus by means of which they performed their experiments. The work of the eighth grade proceeded in the same manner through experimentation with simple, usually improvised apparatus, construction work, and constant discussion of the significance of the experiments. The experiments are introduced either as outcomes of questions that have arisen from previous experiments or from discussion of common phenomena of the home or environment. While the year's work takes up topics as, heat, sound, light, liquids, gases, and simple machines, and thus seems rather formal from this statement of topics, the treatment is informal, and aims to consider topics as they are illustrated in common phenomena that may be observed by any pupil in his everyday experiences. We do not regard the organization of significant topics as ideal, but the outline represents the present stage of our experiments in organizing this part of the elementary

[1] This is an outline of work as taught by Mr. C. F. Phipps who has assisted in the preparation of this paper.

[2] It is unfortunate that other illustrations intended for this article were defective and could not be used.

science course. No attempt is made to use the organization of topics that would be found in an ordinary course in elementary physics. The topic *heat*, its nature and application, is the first subject of study of the eighth year. The following outline presents the experiments used in the first part of the study. The notes suggest what the pupils observed, what conclusions they reached, and sometimes the chief points of the discussion are added.

I. Heat, Its Nature and Applications as Shown by Experimentation with Common Materials and Through Observation of Common Phenomena.

At the outset the topic of study is announced, and questions are asked regarding what seems to be the importance of the study. Questions are asked that center attention on heat effects in the home, as in boiling water, cooking, maintaining desired temperature of the home by hot air, steam, or hot water, evaporation from surface of water, etc. The pupils are encouraged to suggest as many cases of application of use of heat or its regulation as they can, and all the discussion is finally centered on the question of boiling, it being made certain that some of the questions that are not understood by the class are brought out. In this way the necessity of experiment and trial is clear and as a result there is a problem or several problems that the class attacks by means of experiment. The topics and the experiments follow. It must be understood that while the order of topics and experiments is decided by the teacher, he is always ready to introduce a pertinent experiment that a pupil may present if it is feasible for trial of a point in question.

IA. *Boiling water.*

1. Use tea kettle filled with water and standing above flame. Observe what happens.

(1) The singing of the kettle is noted. Explanations are called for, and various explanations are offered. Pupils cannot explain singing fully —cannot be understood until they know something about bubbles that are coming up in the water in the kettle. Some explanation is given by the teacher, and full explanation is delayed until other facts are noted.

(2) Vapor seen at the spout of the kettle. Thought by the pupils to be steam. No vapor is seen at the end of the spout, but at a little distance from it. Why? Various explanations, the correct one being given by pupils as that the steam turns to vapor.

(3) Cause for the steam turning to vapor. Explained by class as due to condensation of steam when in contact with the cold air.

(4) Relation of the facts just seen to fogs and clouds. Questions and collection of previous observations led to explanation and understanding of relation of vapor to cloud formation.

(5) Tests of vapor to see its nature.

Put flame in it, and see it dissipate. What becomes of it?

Put cold glass plate in it and observe results. Condenses on glass. Because glass is so much colder than the vapor.

Put glass plate in the invisible steam. Same results. Accounted for by class by combining the two previous steps—making steam into vapor and condensing vapor on glass.

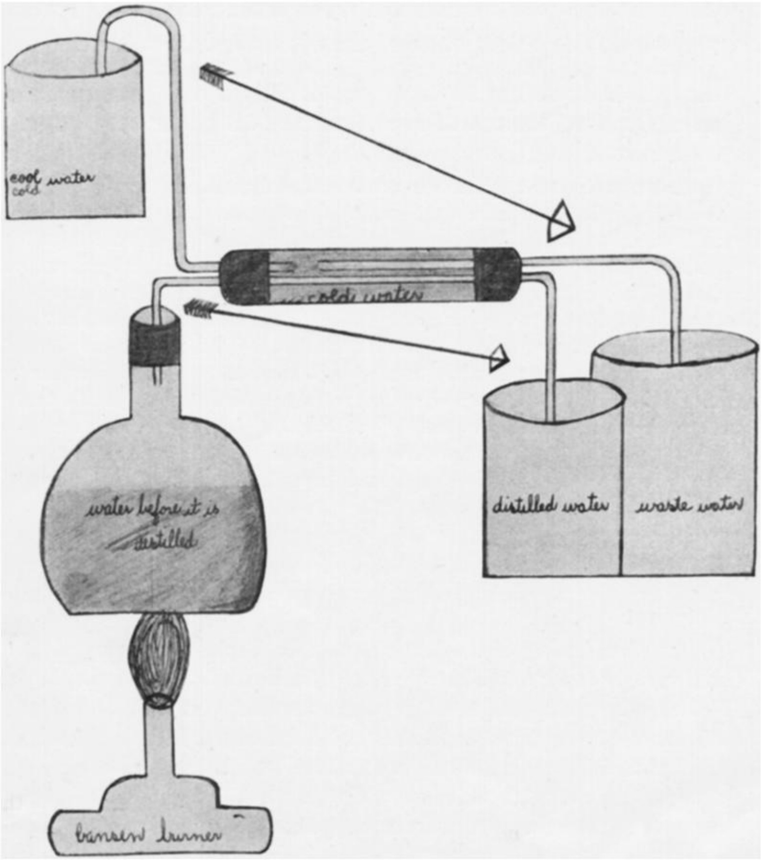

FIG. 1.—A pupil's drawing illustrating his apparatus for distilling water

(6) What will be the effect if we close the spout? How shall it be closed? Why not with hand? Close it with cork stopper.

Steam is found to make the cover rise and fall. Does it rise and fall slowly? At regular intervals? Explain if possible the intermittent rising and falling, and any differences in the rapidity of the rise and the fall.

(7) Experiment with stoppered test tube. Cork the tube and boil the water. Cork is blown out. Explain. Decided that the expansive force of the steam forces the cork out.

(8) Experiment with a glass of water to see if there is air in the water. Put glass of water on radiator, register, or upon stove and leave standing until quite warm. Noted that after a time small bubbles of air gathered on inner surface of glass. The temperature of the room or whatever the glass stood upon caused the air to be forced out of the water, and they gathered on the walls of the glass. Shake the glass and note the rise of the air bubbles through the water. Have pupils repeat this experiment at home under the variety of circumstances that are offered. It will be noted that water from the faucet often appears muddy when first drawn, and soon settles as the bubbles of air rise to the top.

(9) Experiments with individual flasks of water when heated.

(*a*) Air is driven out in the form of tiny bubbles.

(*b*) Steam bubbles observed by some as first rising but bursting before reaching the top of the water in the flask.

(*c*) Larger bubbles of steam rise and burst on surface. The latter is called boiling.

(*d*) Why do the bubbles rise? They are lighter. Why lighter? Because the air is expanded and steam bubbles are gaseous water, so lighter than water. (Do not follow this further at this time.)

(*e*) Moisture, then, drops of water noted on neck of flask. The flask is in contact with lower temperature of outside air. Cause? Condensation. Pupils note that enough steam condenses so some drops flow back to the water below.

(*f*) Insert into mouth of flask a cork with bent glass tube through it, so arranged that steam is passed through the tube.

(*g*) More moisture and drops noted in the tube. Why? More prolonged exposure to condensing influence of lower temperature. Finally no more steam condenses in neck of flask or in bent tube. Why? Because they have become so hot by the constant passage of steam that they are no longer cold enough to condense steam.

(*h*) Steam at nozzle, then vapor. Why? Further condensation.

(10) Problem: How hot is water when boiling?

(*a*) Pupils put thermometer through two-hole cork down into water or hold by string or wire, and test. (Used both Centigrade and Fahrenheit.)

How much higher will thermometer register if allowed to remain in the boiling water a few minutes? Pupils are surprised to find it does not rise above 100° or 212° no matter how long held there while water is boiling over the gas flame. Not wise to explain now that the evaporation surface is increased, when steam bubbles form, to

just such an extent that the *loss of heat* because of evaporation exactly equals the heat received from the fire.

(11) Problem: Is the steam that is given off hotter than the water?

(*a*) Hold thermometer in steam just above boiling water. Compare temperatures.

(12) Problem: Do other liquids boil at same temperature as water, and produce steam at same temperature?

(*a*) Try alcohol. Boils at 78°C. Vapor of alcohol also in 78°.

(13) Problem: Would water boil at same temperature if something was dissolved in it.

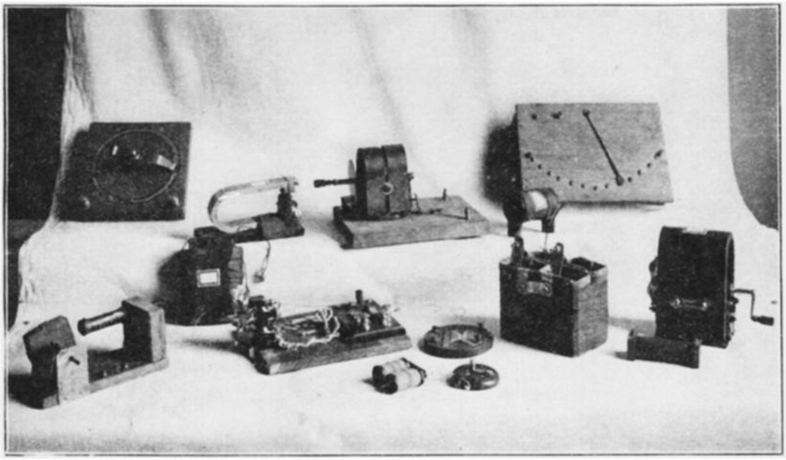

FIG. 2.—Apparatus made by seventh grade when studying electricity and magnetism.

(*a*) Try salt, first a little, then a larger amount. More heat needed. Found that it boiled at higher temperature with material in solution. Found that it boiled at 103° C. with amount of salt that was used. Would more salt alter the temperature of boiling? Try it. The boiling temperature rises.

(14) Problem: Is it possible to boil water with less heat than 100°C. or 212°F.?

(*a*) Boil water in flask, and while steam is escaping cork up tight, invert the flask and, soon as boiling ceases, pour cold water over flask. Repeat as long as boiling can be made to occur.

(*b*) Discussion as to causes.

Pupils note that the cold water condenses the steam in the flask, and as the air was all driven out by the steam before corking, there must be a partial vacuum. Further

discussion brings out the facts that water *not* corked up boils at 100° because it takes that much heat to make bubbles which will lift off the air pressure. In the partial vacuum in the flask, after the cold water condenses the steam, there is very little pressure on the water so it boils easily at reduced temperature.

(*c*) Soon as boiling no longer occurs take temperature of the water. May be 25° or 30°C.

(*d*) Was it hard to get cork out? Why? Partial vacuum within and air pressure on cork pushed it in. Concluded that air pressure affects temperature of boiling.

(*e*) Relation of heat of boiling water to cooking.
Questions and discussion.

(*f*) Would such things as potatoes, beans, etc., cook in the water at last temperature found?
Concluded that potatoes would not cook at that temperature.

(*g*) Do campers find any difficulty in cooking on high mountains? Why?

A few important facts are that:
In Madrid 3,000 feet high, water boils 206°F. = 97 C.
In Quito 11,000 feet high, water boils 194°F. = 90°C.
On Mt. Blanc 15,000 feet high, water boils 180°F. = 82°C.

Again, in the boiler of a steam engine in which the pressure is 100 pounds to square inch the boiling point of water is 155°C.

IB. *Evaporation.*

1. What effect has the sun and dry warm air on bodies of water? General discussion of problem. Pupils say, sun draws water up. What does this mean? Explanation.

2. Can this evaporation be made to occur more rapidly? How? Heating or boiling.

3. Relation of boiling to evaporation. Made clear by discussing previous experiment and general experience.

4. Pupils weigh water in pans and set aside and weigh each day for several days. Causes of less water in pans.

5. Use different sized dishes and solve problem whether same amount is evaporated from each. Found to depend upon amount of surface exposed.

6. Aids to explanations of evaporation. Discussion.

(*a*) Larger the surface, faster evaporation. Why? More heat and air get at the water.

(*b*) Warmer the room, faster evaporation. Why? The more heat, the faster the molecules of water vibrate and the more fly out into the air.

(*c*) What would happen if the pans were fanned all day? Set one pan in air current and compare with one in still air. More rapid evaporation. Why?

(*d*) Why do clothes on the line dry better on a windy day? Saturated air about the clothes is blown away and drier air takes its place and absorbs moisture faster from the clothes.

(*e*) Take same weight of water as in (4) above, boil it for a few minutes and weigh again. In a few minutes as much water evaporated as did in several days when left standing in rooms.

7. Do other liquids evaporate at same rate as water?

Put 3 drops each of water, alcohol, and ether on a piece of glass and time the evaporation of each.

Try again, and fan the drops. Quicker evaporation is noted and same relative periods for each as compared with others.

Pupils raised this question—When the water evaporates from the ocean, does the salt go up with the water? Dissolved salt in a test-tube of water, poured a few drops into a teaspoon on a piece of sheet metal and heated gently. Water evaporated and left the salt behind.

What are the conditions about Great Salt Lake, Utah? Some pupils have seen conditions there and explained the situation.

IC. *Condensation and distillation.*

1. Repeat boiling of water in flask until corked with tube inserted to see steam condense in the glass tube.

2. Put cold object in the steam. Observe condensation on cold object. Why this condensation? Reduction of temperature and condensation.

3. Can the steam be changed to water faster and in larger quantities than in the preceding experiments? Discussion by teacher and class.

4. Have pupils devise and make drawings of apparatus for securing water by condensing. Most of the pupils brought in sketch of plans for condensing and securing water therefrom.

5. Each put his drawings on board and explained. Class criticism of all plans.

6. Best plans were used by pupils in making and setting up apparatus. Water boiled and condensed the steam. Water secured thereby.

7. Can any practical use be made of these processes? Suggestions by class.

8. Try muddy water, colored solutions, salty solutions.

9. What is the process called? Distillation.

10. Application of distilling to industrial life. Discussions by teacher and pupils. Purifying water; making liquors and alcohol; making kerosene, naphtha, etc., from petroleum.

Following these experiments, there were others on topics related to heat as follows: effect of heat on solids, heat and cold by chemical action, effects of heat on liquids, effects of heat on gases, heat conduction in water; then special topics were made of the Thermos

bottle, temperature and the thermometer; sources of heat, the application of heating processes, cooling processes, and ice making. This work occupied the time of the class during most of the autumn and winter quarters. In the spring quarter, first there came work with glass tubing; cutting, bending, drawing, sealing, making pen-filler and delivery tubes. This work is interesting and instructive in itself and serves well in assisting the pupils to make apparatus to be used later.

Solids, liquids, and gases were taken up by means of experiments; also solutions, crystallization, water pressure, pumps, buoyancy, flotation, specific gravity, air as a gas, air pressure, coal gas, ammonia, carbon dioxid, photography as a means of study of the light, and a few experiments on sound.